Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 196 (2017) 1018 – 1025

Procedia Engineering

www.elsevier.com/locate/procedia

Creative Construction Conference 2017, CCC 2017, 19-22 June 2017, Primosten, Croatia

# Detection of Architectural Drawings Errors in 3 Dimension

Aynur Kazaz[a], Turgut Acıkara[b]*, Serdar Ulubeyli[c], Hasan Koyun[d]

[a,d]*Akdeniz University, Antalya, 07058, Turkey*
[b]*Alanya Aladdin Keykubat University, Antalya, 07450, Turkey*
[c]*Bulent Ecevit University, Zonguldak, 67100, Turkey*

**Abstract**

In construction projects architectural drawings are the main documents which show how a structure has to be built. In this sense, most of the data necessary for project management are prepared based on these drawings. Therefore, architectural drawing errors will adversely affect the constructability and hence, the time and cost of a construction project. On the other hand, although the structures are built 3D, architectural drawings are prepared 2D. This circumstance complicates the detection of drawing errors during the design phase. In other words, drawing errors are mostly encountered during the construction phase. In fact, drawing errors are risks which can be detected during the planning phase in nature. In this study, it was argued that to detect drawing errors in planning phase architectural and engineering drawings should be prepared 3D instead of 2D. In this context, drawings of an official approved hotel project were redrawn by means of BIM to determine whether there exists drawing errors. The results of the study revealed that drawings involved many errors and 3D drawings enable early detection of them.


Peer-review under responsibility of the scientific committee of the Creative Construction Conference 2017

*Keywords:* Architectural drawings; building information modeling; constructability; drawing errors; project management.

## 1. Introduction

Construction projects involve numerous uncertainties because of their complex nature. Since, these uncertainties mostly arise in the construction phase; they cause time and cost overruns, and quality reduction in the projects. In this sense, the primary goal of the design phase is to detect and eliminate or take precaution for these uncertainties

* Corresponding author. Tel.: +90-242-510-61-20; fax: +90-242-565-10-99.
*E-mail address:* turgut.acikara@alanya.edu.tr


Peer-review under responsibility of the scientific committee of the Creative Construction Conference 2017
doi:10.1016/j.proeng.2017.08.044

before the construction starts. The interaction between design and construction phases in construction project is defined by the term constructability [1]. The Construction Industry Institute (CII) defines constructability as "the effective and timely integration of construction knowledge into the conceptual planning, design, construction, and field operations of a project to achieve the overall project objectives in the best possible time and accuracy at the most cost-effective levels." [2]. Indeed, constructability is an indicator of the design quality. In other words, if the data obtained in the design phase are difficult to understand and interpret, then constructing the building will be so much complicated [3].

Many researches in the literature revealed that design errors are one of the most important risks in construction projects which cause time and cost overruns. Risk is simply defined as a condition which arises under certain circumstances with adverse effects. In other words, risk is a probabilistic condition. On the other side, architectural and engineering drawings show the dimensions and positions of the construction elements. To be constructible construction elements have to match up with these drawings after they are built.

In this sense, although drawing errors are often encountered in projects, they are preventable risks in nature. Indeed, drawing 3D construction elements in 2D prevents encountering the errors in the design phase. In this study, it was argued that architectural and engineering drawings should be prepared 3D to remove drawing errors before the construction starts. In this context, official approved drawings of a hotel project were redrawn as 3D by mean of BIM and potential errors which would be encountered in construction phase were determined.

## 2. Theoretical background and methodology

Basically, in design phase of construction projects it is determined how to meet customer requirements. In this context, design phase consists of two successive steps. In the first step, the architectural and engineering drawings are prepared from which also the other activities of design phase are derived. Based on these drawings in the second step the construction, procuration and management activities of the project are planned [4]. Although decisions made in design phase have a big impact on the projects' time, cost and quality, they are taken with insufficient information [5]. This uncertain nature of the projects is prone to design errors which are mostly detected in the construction phase.

Since the design phase is too comprehensive, design errors also varies. However, design errors causing rework and design changes are accepted as the primary contributor to time and cost overruns [6]. 70% of reworks in construction projects are caused by design errors [7]. Although, design errors are hard to detect before the construction starts [8], errors are the products of a person's cognitive capability and hence, they may be prevented [9]. In this sense, it is crucial to determine the design errors which can be detected before the construction starts.

Architectural and engineering drawings are a sort of installation guides for construction projects. They show the geometry and position of each construction element that will be built. Therefore, for a correct production these drawings should not include errors. However, in today's construction industry 3D construction elements are build based on 2d drawings [10]. In other words, the restricted visualization provided by 2d drawings prevents the early detection of errors. On the other hand, Building Information Modelling (BIM) software which became popular in the recent years allows preparing a 3D visual model of the buildings. BIM provides an accurate geometrical representation of construction elements in an integrated data environment [11]. In addition, BIM also combines the separately prepared architectural and engineering drawings in a simple drawing. In this aspect, project participants can see what will be built in a simulated environment and identify potential drawing errors before the construction starts [12]. In this study, it was assumed that drawing errors are detectable in the design phase and argued that preparing the drawings 3D with BIM software instead of 2D will ease the detection of these errors. In this context, official approved drawings of a hotel project was redrawn as 3D by mean of BIM and checked whether drawing errors exists.

## 3. Findings

In context of this study architectural and engineering drawings of a 5 star hotel which is built in Antalya were redrawn by means of BIM. The project consists of 3 main blocks and 12 villas and has a construction area of 35.700 $m^2$. The estimated time and cost of the project were 13 months and 3.200.000 €, respectively. However, the project was accomplished with 2 months delay and 300.000 € cost increase.

In context of this study architectural and engineering drawings of a 5 star hotel which is built in Antalya were redrawn by means of BIM. The project consists of 3 main blocks and 12 villas and has a construction area of 35.700 $m^2$. The estimated time and cost of the project were 13 months and 3.200.000 €, respectively. However, the project was accomplished with 2 months delay and 300.000 € cost increase.

### *3.1. Conflict between architectural and electrical drawings*

This error was caused by the conflict between architectural and electrical drawings. In 2D architectural drawing the power sockets were located 20 cm apart from the door trim in the hotel rooms (Figure 1). However, after the electrical drawing was combined with the architectural one by means of BIM it turned out that power sockets overlap with the door trim (Figure 2). To overcome this problem the places of the power sockets were changed after revising the electrical drawing.

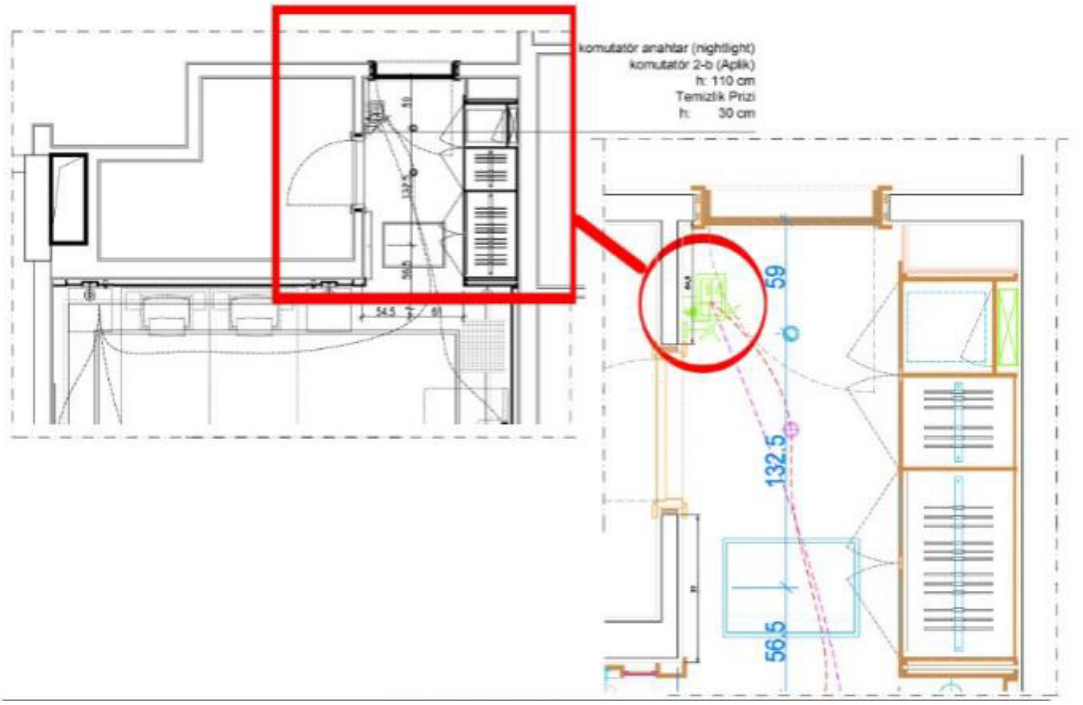


Figure 1. Location of the power sockets

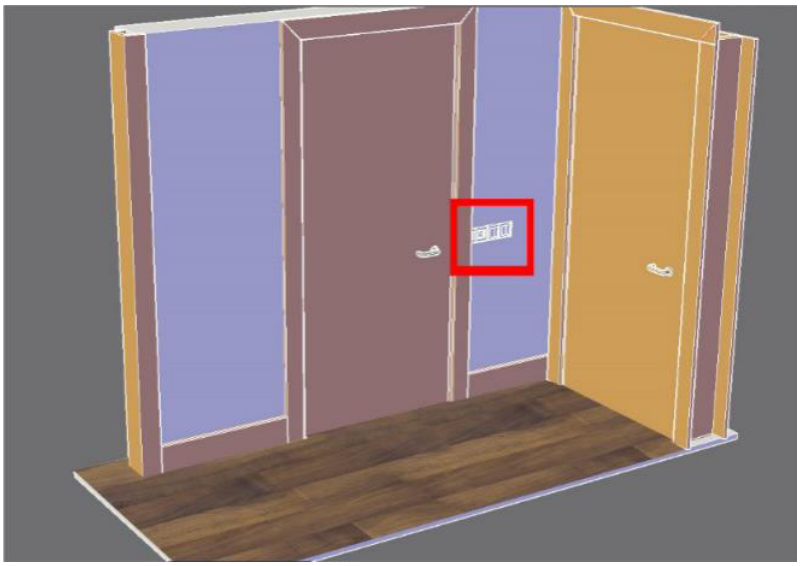

Figure 2. Overlap of power sockets with the door trim

### *3.2. Conflict between electrical and mechanical installation drawings*

This error was caused by the conflict between electrical and mechanical installation drawings. According to the architectural drawing the wall box is located on the outer surface of the shaft gap where the pipelines in it (Figure 3). However, form 3D drawing it was observed that the pipelines were passing through the wall box (Figure 4). Similar to the previous error the electrical drawing was revised and the place of the wall box was changed.

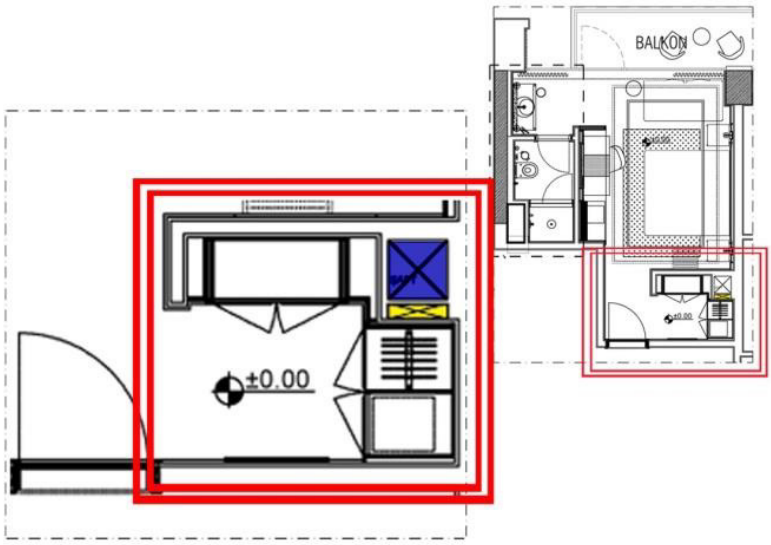


Figure 3. The location of Wall box and pipelines

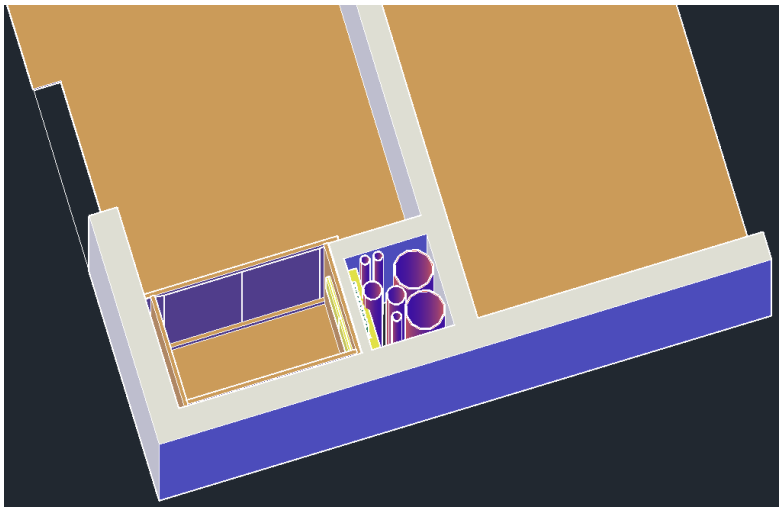

Figure 4. Intersection of wall box with pipelines

### *3.3. Conflict between structural and mechanical installation drawings*

The last conflict error was observed between structural and mechanical installation drawings. Since these drawings are prepared separately by different engineers, it is almost impossible to detect them unless the drawings are combined to a single drawing in the design phase. As seen from Figure 5, after these drawings were combined with BIM it turned out that the pipelines in restrooms pass through the load-bearing column of the hotel. In practice, the mechanical installation drawing was revised and accordingly, the location of washbasins was changed.

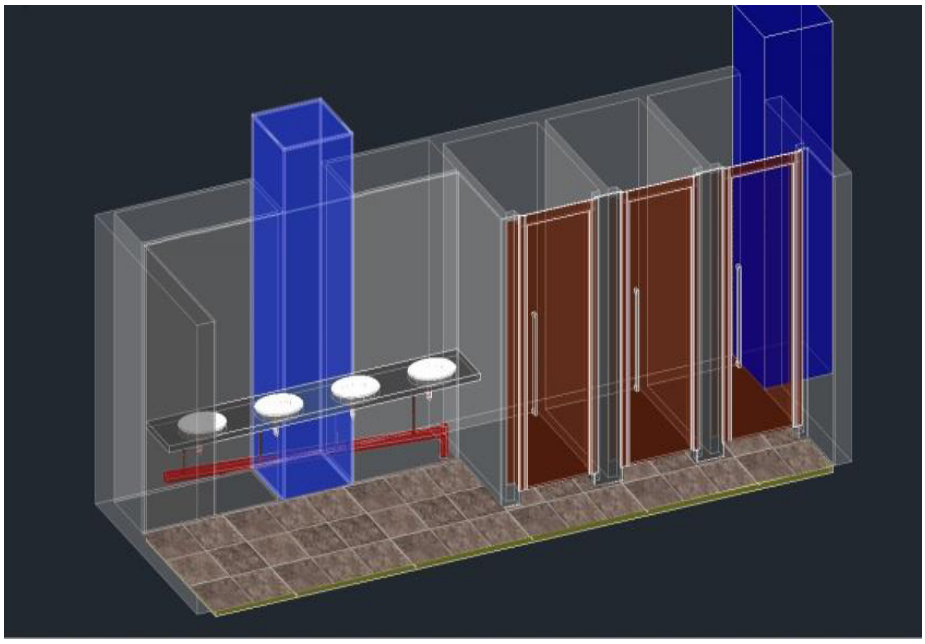

Figure 5. Intersection of pipelines with load-bearing column

### *3.4. Error in the fire escape*

This error was encountered in the fire escape. According to the architectural drawing 2 doors were placed on the bottom of the fire escape (Figure 6). However, after the fire escape was drawn 3D it was observed that the elevation of the doors was not calculated accurately in 2D drawing and hence, the doors intersected with the stair landing (Figure 7 and Figure 8). In practice to overcome this problem the doors were canceled.

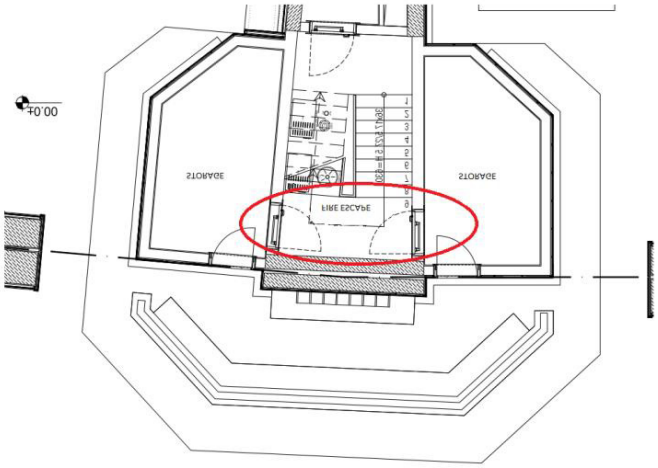


Figure 6. Location of the doors in architectural drawing

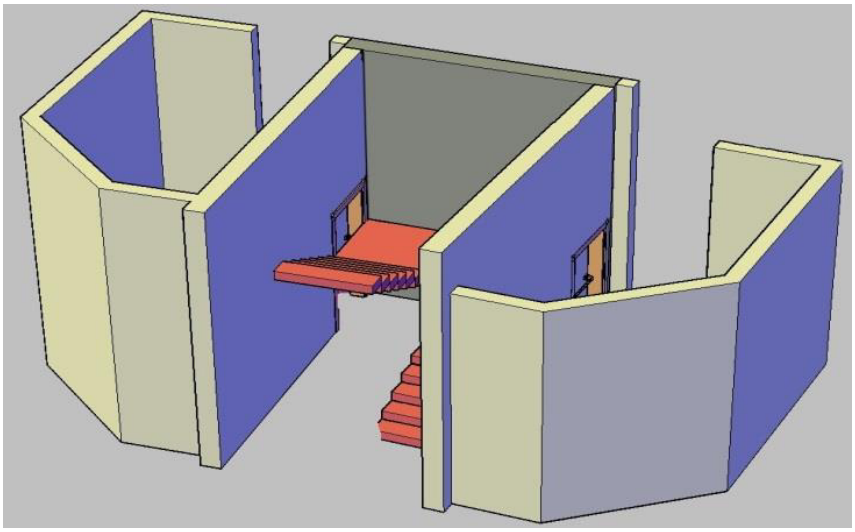

Figure 7. Side view of the error

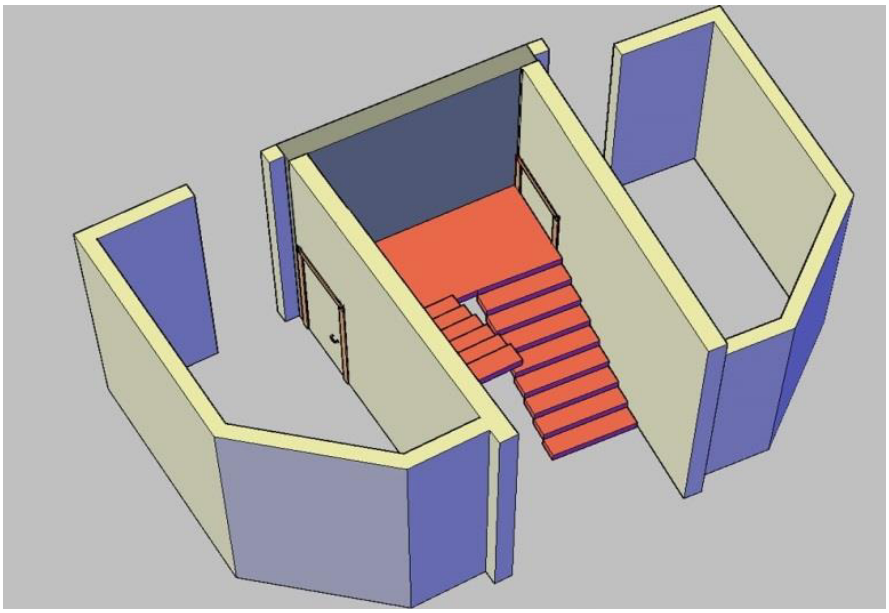

Figure 8. Top view of the error

### *3.5. Error in architectural drawings*

The last error was detected in the architectural drawing of the villas. In 2D drawing a window was placed near the stairs for lighting purposes. Similar to the previous error, the elevation of the window was not calculated accurately and hence, the window intersected with the stair (Figure 9 and Figure 10). Since revising the architectural drawing would take much time, the window was canceled in the practice.

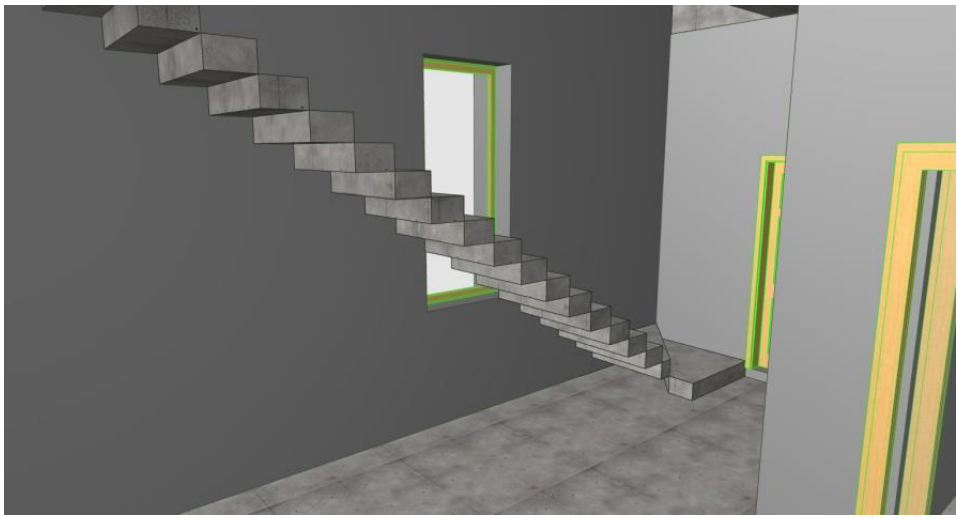

Figure 9. Inside view of the error

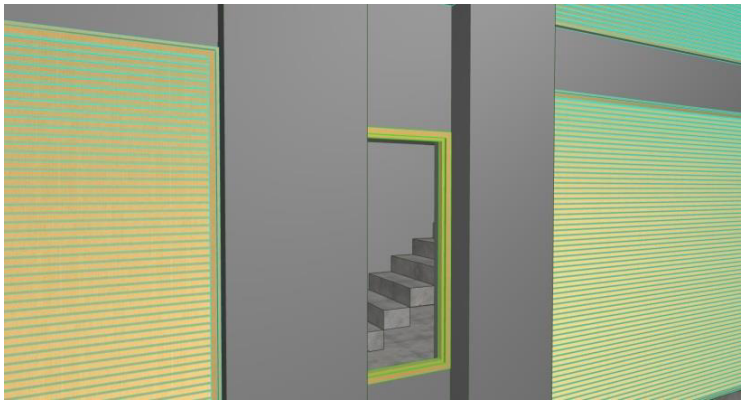

Figure 10. Outside view of the error

## 4. Conclusion

Accomplishing a construction project within its scope is the primary goal of project management. However, the dynamic nature of the projects involves numerous uncertainties. Most of these uncertainties arise in the construction phase which causes delays, cost overruns and quality reduction in the project. Therefore, detecting these uncertainties and taking countermeasures in the design phase is crucial for project management.

Drawing errors are one of the most encountered error types in construction projects. Although, these are accepted as uncertainties, they are preventable in nature. In this study it was argued that preparing the drawings in 3D with BIM which also combines all of the drawings into a single one, would provide an early detection of drawing errors in the design phase. For this purpose, official approved drawings of a hotel project were redrawn with BIM and 5 drawing errors were encountered. Indeed, all of these errors were really encountered during the construction of the hotel. Therefore, this study proved that conventional preparation of drawings prevents the early detection of drawing errors. In other words, to eliminate the drawing errors in the design phase all architectural and engineering drawings should be combined in a single drawing and drawn 3D.

## References

[1] Y.Q. Yang, S.Q. Wang, M. Dulaimi, and S.P. Low, "A fuzzy quality function deployment system for buildable design decision-makings" *Automation in Construction*, Vol. 12, pp. 381-393, 2003.
[2] (2016) The CII website. [Online]. Available: https://www.construction-institute.org/Store/CII/Publication_Pages/
[3] J.A. Gambatese, M. Hinze, and M. Behm, "Investigation of the Viability of Designing for Safety" The Center to Protect Workers' Rights, May 2005.
[4] D.R. Pierce, Project Scheduling and Management for Construction. John Wiley & Sons, U.S.A. 2013.
[5] A. Ward, J.K. Liker, J.J. Cristiano,. And D.K. Sobek, "The second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster", Sloan Management Review, Vol. 36, pp. 43-61, 1995
[6] S. Han, P. Love, and F. Pena-Mora, "A system dynamics model for assessing the impacts of design errors in construction projects", Mathematical and Computer Modelling, Vol. 57, pp. 2044-2053, 2013.
[7] P.E.D. Love, D.J Edwards, and Z. Irani, "Forensic Project Management: An Exploratory Examination of the Causal Behavior of Design-Induced Rework", IEEE Transactions on Engineering Management, Vol. 55, pp. 234-247, 2008.
[8] H.M. Haydl, and A.W. Nikiel, " Design and construction errors", Practical Periodical on Structural Design and Construction, Vol. 5, pp. 126–130, 2000.
[9] J.T. Reason, and A. Hobbs, Managing maintenance error: A practical guide, Ashgate Publishing Company, Aldershot U.K., 2003
[10] B. Succar, "Building information modelling framework: A research and delivery foundation for industry stakeholders", Automation in Construction, Vol. 18, pp. 357-375, 2009.
[11] CRC Construction Innovation, Adopting BIM for facilities management: Solutions for managing the Sydney Opera House, Cooperative Research Center for Construction Innovation, Brisbane, Australia, 2007.
[12] S. Azhar, "Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry", Leadership and Management in Engineering, Vol. 11, pp. 241-252, 2011.